Electron Theory of Solids
EGRE 520

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Objective: This course is intended to provide the student with the background needed to understand the principles behind modern quantum devices. The first five topics deal with classical optics concepts needed to understand solid state lasers. The remaining topics address transport physics needed to understand the principles behind modern electron devices.

Pre-requisites: Senior undergraduate level quantum mechanics (or first year graduate level quantum mechanics with knowledge of Schrödinger Equation and particle-in-a-box states), and basic solid state physics and solid state devices.

Course Topics

1. Optical devices: Density of states of photons, Planck's blackbody radiation (1 lecture)
2. Electron photon interaction, absorption, spontaneous emission, stimulated emission (3 lectures)
3. Van Roosbroeck Shockley relation (1 lecture)
4. Population inversion, importance of degeneracy (1 lecture)
5. Bernard Durrefourg conditions, optical gain and cavity feedback, mode hopping (1 lecture)
6. Calculation of threshold current for lasing (1 lecture)
7. Electron quantum devices: Schrodinger equation formalism of quantum mechanics (1 lecture)
8. Ehrenfest theorem and other useful theorems in quantum mechanics (1 lecture)
9. Time independent perturbation theory (1-2 lecture)
    a. Device application: quantum confined Stark effect
10. Schrodinger equation in a periodic potential, Bloch theorem(1 lecture)
11. Band structure calculations, nearly free electron model, tight binding approximation, augmented plane wave expansion, k•p perturbation (3 lectures)
12. Density of states in 0-d, 1-d, 2-d and 3-d (quantum dots, quantum wires, quantum wells and bulk) ((2 lectures)
13. Transport formalisms: Boltzmann transport equation (1 lecture)
14. Relaxation time approximation, Drude model (1 lecture)
15. Fermi's Golden Rule, calculation of matrix elements and scattering rates (1 lecture)
16. Electron phonon scattering, electron impurity scattering rates (1 lecture)
17. Generalized moment equation. Derivation of hydrodynamic (drift-diffusion) equations (1 lecture)
18. Sturm Liouville equation, density matrix formalism (1 lecture)
19. Linear response quantum transport; Landauer Buttiker formalism (1-2 lectures)

20. Calculation of transmission probabilities in devices (1 lecture)
21. Applications of Landauer Buttiker formulas: resonant tunneling devices, Aharonov-Bohm interferometers, bend resistance, T junction transistors (1 lecture)
22. Integral quantum Hall effect from the Buttiker viewpoint (1 lecture)
23. An electron in a magnetic field; the concept of gauge (1 lecture)
24. Landau levels; edge states (1 lecture)

Useful references:

- S. Datta, Transport in Mesoscopic Devices, Cambridge University Press
- S. Datta, From Atom to Transistors, Cambridge University Press
- D. K. Ferry, Quantum Mechanics, Taylor and Francis

Homework:

Homework problems will be assigned in class, one week before they are due. Solutions will be e-mailed to the instructor as a pdf file. Mid-term and final exam solutions will also be e-mailed to the instructor in a pdf file on or before the due date.

Class grade will be based on the homework, mid-term and final.